

Research on Controlled Flight Into Terrain Risk Analysis Based on Bow-tie Model and WQAR Data

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ABSTRACT

Controlled flight into the terrain (CFIT) is the main types of civil aircraft accidents. In this paper, we build the risk model for CFIT event, which is based on Bow-tie analysis model. At the same time, we calculated and verified this model by using China civil aviation flight quality monitoring station's A320 fleets of flight data, and analyzed the results based on the time dimension and China's domestic airport dimension, finally achieved the warning function of CFIT event risk.

INTRODUCTION

Controlled Flight into Terrain (CFIT) is an accident in which an airworthy aircraft, under pilot control, is unintentionally flown into the ground, a mountain, a body of water or an obstacle [1]. According to the Boeing Company for 65 jet aircraft accidents statistics which were occurred in 2006-2015 [2], CFIT accidents accounted for 21.5% of all accidents.

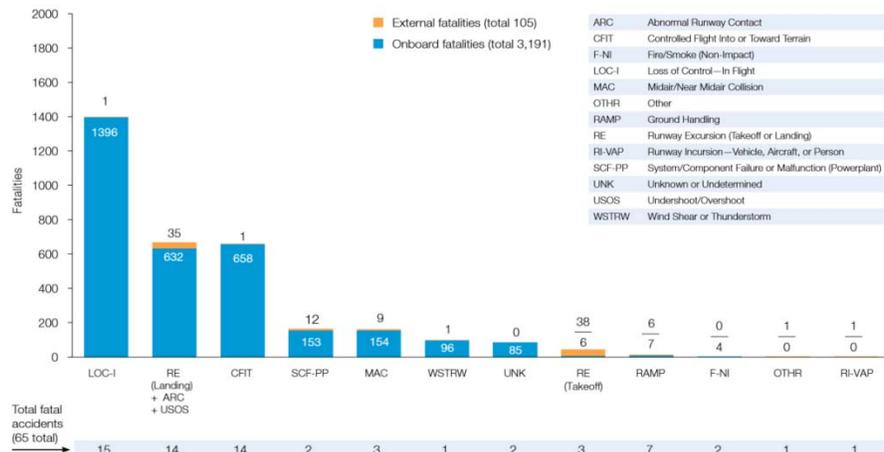


Figure 1. Boeing statistics for 2006-2015 civil aviation accidents.

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At present, the CFIT problems are studied by using traditional analysis methods including Safety Checklist Analysis,(SCA), Preliminary Hazard Analysis(PHA), Failure Modes Analysis(FMA), Fishbone Analysis, fault tree analysis (FTA), event tree analysis (ETA) and so on. The combination of FTA and ETA can analyze the whole process of accident occurrence, such as accident preventions, controls, occurrences, consequences and causes. However, the method of FTA and ETA cannot provide a visual assessment of the causes, consequences and adequacy of the hazard events. Therefore, if the combination of FTA and ETA analysis based on the Bow-tie Analysis Model, can be a good solution to this problem.

INTRODUCTION TO THE BOW-TIE MODEL

Bow-tie model was proposed by the University of Queensland in 1979, and the Royal Dutch /Shell Group of Companies put it into commercial practice firstly[3]. This model has been widely used in the field of safety risk analysis and safety management in recent years because of its intuitionistic and concise features. The structure of Bow-tie model is shown in Fig.2. We can see that the model is composed of five parts: Hazard, Prevention Controls, top event, Recovery Controls and Consequence.

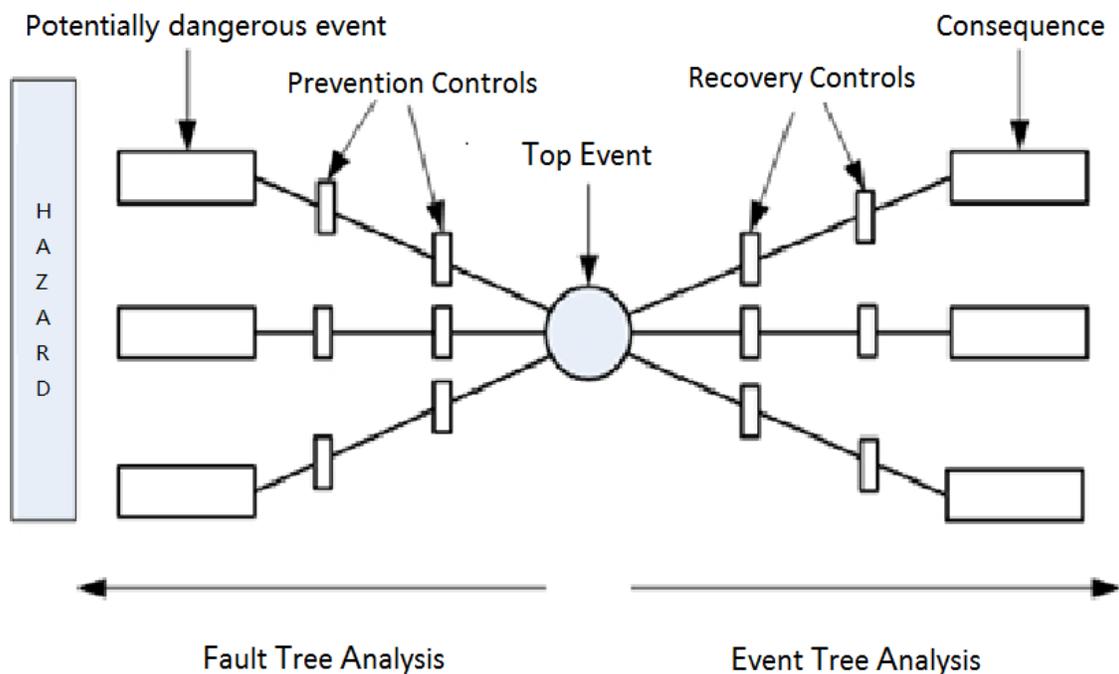


Figure 2. The structure of Bow-tie Model.

Hazard: Anything that could create a risk and cause an accident. It Includes the injury to people, the damage to equipment or structures, the resulting in material loss, the state, objects, activities or events which are reduced the implementation of the provisions of the functional capacity. Eurocontrol defines a flight safety hazard as any state, event or circumstance that triggers an incident. Hazard identification is the act of identifying a fault condition or a symptom of a top-level insecurity event and defining the nature of the hazard event in terms of potential safety outcomes and their effects.

Top Event: A single incident, major cause, symptom, or precursor event that together results in an adverse event with another risk event.

Prevention Controls: A system, activity, action, or procedure set up to reduce the risk associated with a hazard before it occurs. Prevention Controls include the elimination of risk (preferred), the reduction of risk frequency (barrier), the possibility of reducing the likelihood of dangerous results, reduce the severity of dangerous results and so on.

Recovery Controls: Controls are taken to restore normalcy or to reduce the risk or to reduce the severity of the outcome after a top event has occurred. Preventive Controls and Recovery Controls can often be referred to as safety barriers.

Consequence: An event or condition caused by an accident. As a result of injury to people, damage to equipment or structure, loss of raw materials or reduce the implementation of the provisions of the degree of functional capacity.

The Bow-tie model combines the two methods of event tree analysis and fault tree analysis to quantitatively analyze the system risk. It has high application value for airline safety risk analysis of the organization defect and human error. The complete Bow-tie diagram can be used to illustrate hazards, top events, risk events, and their potential consequences, as well as risk control mechanisms established to minimize risk.

CFIT RISK MODEL BASED ON BOW-TIE

ICAO has always focused on the risks of typical events such as Controlled Flight into Terrain, Lost Of Control and runway overrun/ excursion, and at the same time, the prevention of these incidents is also the focus of China civil aviation safety. CFIT flight accidents usually occur in instrument meteorological conditions (IMC), flights in night, or both conditions of low visibility conditions. This is mainly due to the lack of the pilots' environmental awareness of the aircraft's vertical and horizontal position relative to the ground, surface or obstruction. Therefore, loss of situational awareness (SA) is the leading cause of CFIT accidents.

Through our analyzing, the core risk of CFIT, which is based on Bow-tie principle model can be the shown in Figure 3.

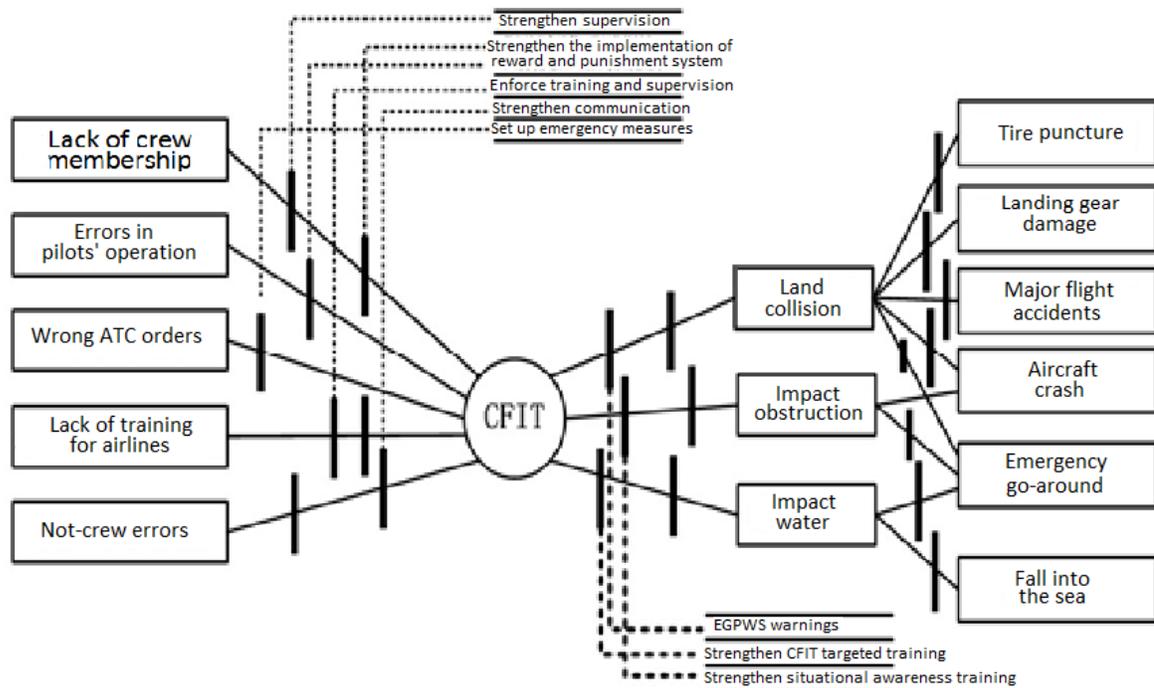


Figure 3. CFIT risk model based on Bow-tie.

The left part of the CFIT risk model based on Bow-tie is the fault tree analysis, CFIT as the top event of the fault tree, and analyzes the accidents and events step by step. Eventually, we can get five basic hazards: Lack of crew membership, errors in pilots' operation, wrong ATC orders, lack of training for airlines, and Not-crew errors.

For each individual base event, we can take the Prevention Controls in the actual operational activities as followings: For lack of qualified crew, training can be strengthened supervision, implementation of the assessment to strengthen the implementation of reward and punishment system; On the pilot's operational errors, the airlines should strictly enforce the retraining, strengthen supervision, control the pilot's human error rate, according to a number of quantitative flight data for flight technology assessment, such as EGPWS/thousand flights; For wrong ATC orders, ATC can strengthen the communication with the crew, strengthen the training and supervision system to ATC; In view of the lack of training of airlines, should strictly abide by the relevant laws and regulations to review and establish safety management system; For Not-crew errors, the corresponding emergency measures should be set up for unexpected emergencies.

After the core risk CFIT is analyzed by event tree, we can find the initial results are the followings: Land collision: result in aircraft tire puncture, landing gear damage, emergency go-around, major flight accidents, aircraft crashes, etc. Impact obstruction: cause the aircraft crash, emergency go-around and so on. Impact water: may result in emergency go-around, fall into the sea and so on.

Recovery controls that can be applied to processes are: When the flight crew receives the EGPWS warnings, it should take the correct measures to deal with it; Airlines should strengthen the response to CFIT emergency targeted training, such as simulator training; Strengthen the pilot situational awareness training and so on.

MODEL VALIDATION USING WQAR DATA

Civil Aviation Administration of China (CAAC) approved the establishment of a Flight Operational Quality Assurance system in 2013, which currently collects more than 2,000 aircrafts' WQAR data from the entire airlines which are operated following CCAR-121 everyday. In this paper, we used the third quarter of 2016 collected 846 aircrafts' and 189,100 flights' WQAR data, which belong to A320 series fleet. And the CFIT risk and data fusion model was established by monitoring the project and parameters such as GPWS warning, high approach speed, deviation of course, deviation of glide, landing and descent rate of non-landing configuration etc. Finally, the CFIT event based on time dimension and the airport dimension risk alert function are realized (see Figures4)

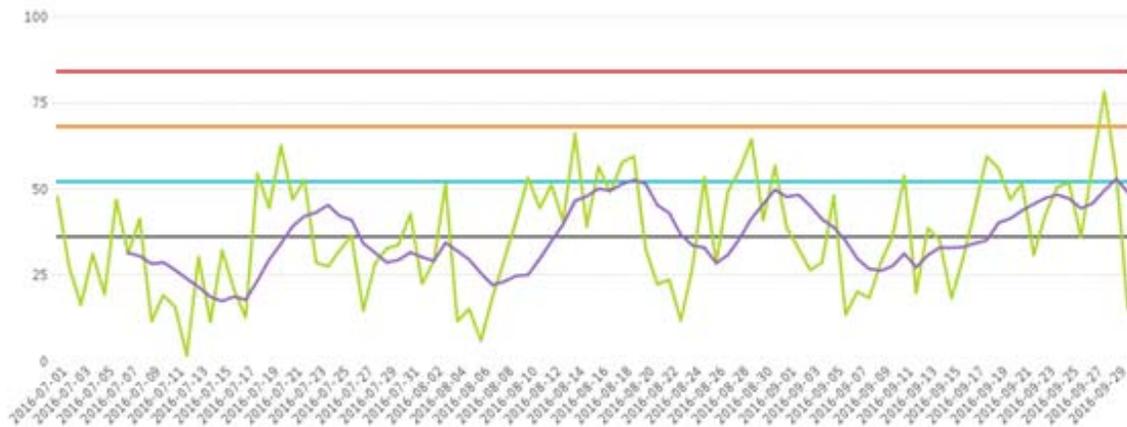


Figure 4. Schematic diagram of time-dimension fusion of CFIT risk.

The Fig4 shows the fusion curve for the A320 fleet in the third quarter of 2016, with CFIT risk in the time dimension (green line), and the purple line is for the 7-day rolling average, the blue line is 1 times the standard deviation, the yellow line is 2 times the standard deviation, the red line is 3 times the standard deviation. It can be seen that 7-days rolling average is basically within one standard deviation, there is no 7-day rolling average out of the alert state, which indicating that the third quarter of the CAAC A320 fleet CFIT risk is at an acceptable level of safety.

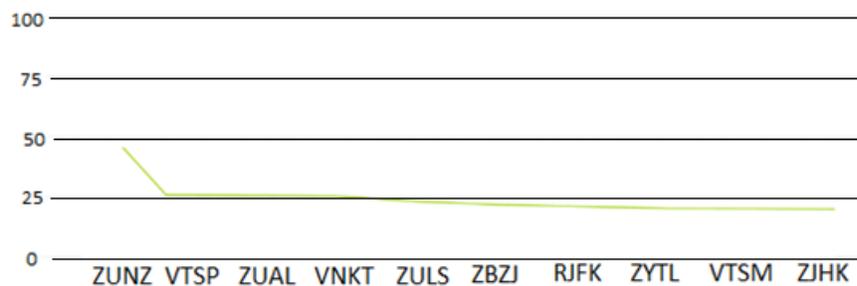


Figure 5. Schematic diagram of airport-dimension fusion of CFIT risk.

The Fig5 shows the top 10 airports with CFIT risk for the A320 fleet in the third quarter of 2016, we can see that Linzhi ,Phuket and Ali airport hit the top 3.

After the integration of the risk value projected to the 0-100 range, It is known that the risk value of CFIT by Linzhi Airport is 42.6, the risk value of Phuket airport is 24.3, the risk value of Ali Airport is 24.2, the CFIT risk of these airports requires attention.

CONCLUSIONS

In all kinds of risk control methods and means, Bow-tie analysis method can be used to express clearly various types of risk problems, to facilitate the understanding of airline managers and staffs. At the same time, the Bow-tie model is concerned with the control of obstacles and their effectiveness for the purposes of prevention and mitigation, and can be used for desired outcomes. In addition, once the establishment of the risk control Bow-tie model, the people who in actual use it, does not require a high level of professional knowledge, it is easy to implement.

In this paper, the author of the international civil aviation industry has been focused on the risk of flight controllable flight, the initial establishment of the Bow-tie model. Based on the A320 series fleet aircrafts' flight data which are collected by China Civil Aviation Flight Operational Quality Assurance system, we achieve the warning function of CFIT risk which is realized by using the risk precaution principle in the ICAO Safety Management Manual[4]. In the future, we will continue to study of Bow-tie Barrier Control and Improve the Fusion Computation Model, and finally achieve the establishment of CFIT risk identification, early warning and control mechanism.

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